Geothermal Briefing







2012

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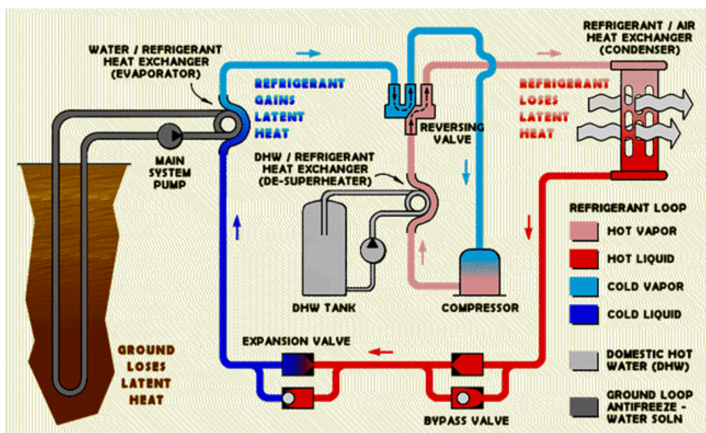
History and the Current Market

The heat pump was described by Lord Kelvin in 1853 and developed by Peter Ritter von Rittinger in 1855. After experimenting with a freezer, Robert C. Webber built the first direct exchange ground-source heat pump in the late 1940s and was credited with using the technology for heating a home with heat stored in the ground. (International Ground Source Heat Pump Association, 2009). The first commercial demonstration of a ground source heat pump (GSHP) was in the Commonwealth Building in Portland, Oregon, in 1946. The technology became popular in Sweden in the 1970s, and has been growing slowly in worldwide acceptance since then. Open loop systems dominated the market until the development of polybutylene pipe in 1979, which made closed loop systems economically viable (Bloomquist, 1999).

A recent number quoted from a 2010 article indicated that there were over 3 million GSHP units installed worldwide in 43 countries. Of the total worldwide capacity, 37% are installed in the United States and Canada, 47% in Europe and 16% in Asia. (Lund, Freeston, & Boyd, Direct Utilization of Geothermal Energy 2010 Worldwide Review, 2010).

Within the U.S., the South has the highest percentage of GSHP installations (35%), followed by the Midwest (34%), the Northeast (20%), and the West (11%) (Lund, Gawell, Boyd, & Jennejohn, 2010). Major GSHP manufacturers are located in the Midwest and South, and correspondingly, these regions have more personnel trained in GSHP installation and maintenance (Navigant Consulting, Inc., 2009). A look at Department of Defense (DoD) facility installations mirrors the installation percentages of the U.S. as a whole. Of the 264 projects representing 21,000 GSHP units in domestic DoD facilities, the majority are located in the Southeast and Midwest, although there are several recent large installations at west coast facilities.



Ground Source Heat Pump Cycle

According to a new report from Pike Research, heat pump sales will experience strong growth rates in the next several years, with annual unit shipments in the United States increasing from just fewer than 150,000 in 2011 to more than 326,000 units by 2017. Putting Wisconsin sales into perspective, in a conversation with a Wisconsin geothermal heat pump supplier, he indicated that approximately 1,000 heat pumps were sold in Wisconsin in 2011 (personal conversation, Urlaub, 2012).

Operating Concept

Ground source geothermal systems operate on the principal of using the earth's natural average underground temperature. The earth surface temperature varies greatly over the course of an average year in Wisconsin. However, the temperature will tend to average out and thermal variation from season to season will dissipate as depth below ground surface becomes greater. At a depth of approximately 20 feet below ground surface, the temperature will trend toward becoming the average of the yearly surface temperature at that location.

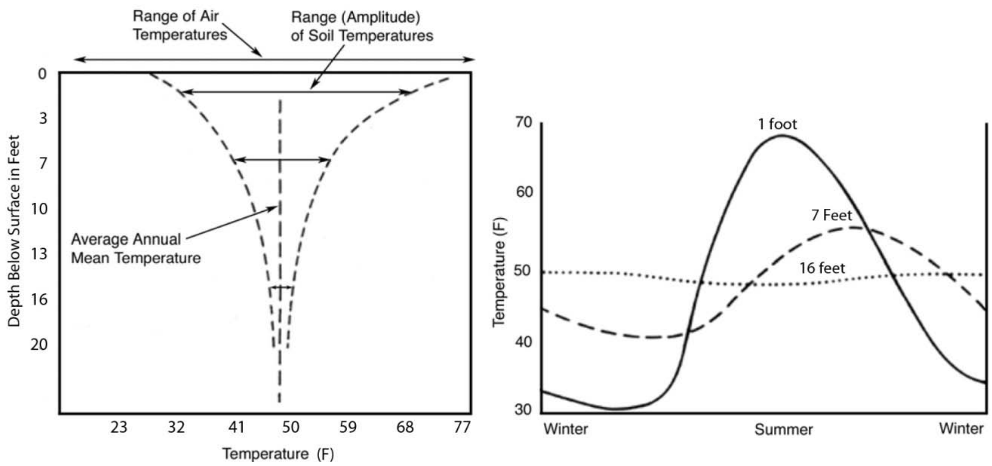
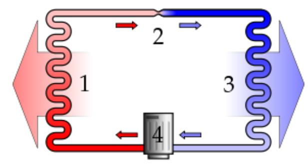


Figure: Depth dependence of ground temperatures (modified from Hanova & Dowlatabadi, 2007)

Mechanical heat pumps or GSHPs exploit the physical properties of a volatile evaporating and condensing fluid known as a refrigerant. The heat pump does work on the refrigerant to make it hotter on the side to be warmed, than at the cold side where heat is absorbed.

A simple stylized diagram of a heat pump's vapor-compression refrigeration cycle: 1) condenser, 2) expansion valve, 3) evaporator, 4) compressor.

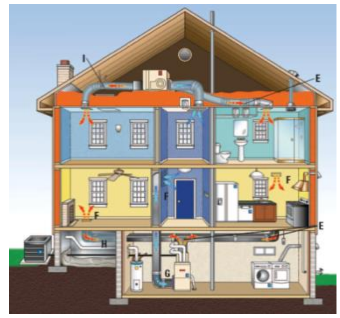


The working fluid, in its gaseous state, is pressurized and circulated through the system by a compressor. On the discharge side of the compressor, the now hot and highly pressurized vapor is cooled in a heat exchanger, called a condenser, until it condenses into a high pressure, moderate temperature liquid. The condensed refrigerant then passes through a pressure-lowering device also called a metering device. This may be an expansion valve, capillary tube, or possibly a work-extracting device such as a turbine. The low pressure liquid refrigerant then enters another heat exchanger, the evaporator, in which the fluid absorbs heat and boils. The refrigerant then returns to the compressor and the cycle is repeated.

In such a system, it is essential that the refrigerant reaches a sufficiently high temperature, when compressed, to release heat through the "hot" heat exchanger (the condenser). Similarly, the fluid must reach a sufficiently low temperature when allowed to expand, or else heat cannot flow from the ambient cold region into the fluid in the cold heat exchanger (the evaporator). In particular, the pressure difference must be great enough for the fluid to condense at the hot side and still evaporate in the lower pressure region at the cold side. The greater the temperature difference, the greater the required pressure difference, and consequently the more energy needed to compress the fluid. Thus, as with all heat pumps, the Coefficient of Performance (amount of thermal energy moved per unit of input work required) decreases with increasing temperature difference (Wikipedia, website).

Primary Heat Pump Components

A GSHP system is typically composed of a ground loop (usually high density polyethylene (HDPE)) plastic tubing that passes through the ground and is used to transferring the earths thermal energy via a circulating fluid), a heat pump (a mechanical system that allows for the extraction of energy from the ground-loop fluid), and a heat distribution system (ductwork system that distributes heat throughout a space).

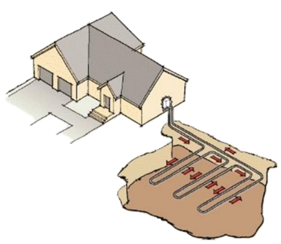


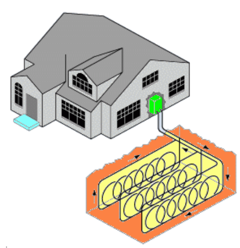
High Density Polyethylene (HDPE) Heat Pump Duct Work

Ground-Source and Water-Source
Using the groundwater or using surface water as a temperature source can be considered a single category because their temperature ranges and heat collection methods are comparable: both pump fluid through a loop and pass it through a heat exchanger.

Common Configurations

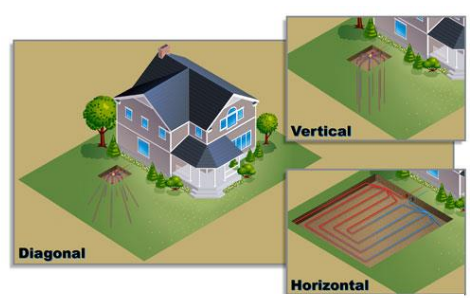
Closed Loop. A closed-loop system comprises a pipe loop located in the ground or a water body. Fluid with a low freezing temperature, such as an ethanol or glycol-water solution, is circulated in this loop. Closed loop systems are more expensive than open loop systems because they require more expensive construction excavation or borehole drilling. They are also more common due to the limitations of open loop systems. Closed loop systems reduce the risk of freeze-up and require virtually no routine maintenance. However, these loops are more susceptible to damage during installation. To prevent fluid release, joints must be heat fused which adds to the construction cost. The length of pipe required is site-specific, and estimates range broadly from 400–600 feet of pipe per ton of heating capacity (NRC Office of Energy Efficiency, 2004) to 720–1040 feet per ton of heat pump capacity (Siegenthaler, 2004). To determine the conductivity at a specific location, a thermal conductivity test must be run, but in Wisconsin a very general number to use for vertical borehole loop conductivity is approximately 180 feet of depth per ton heating capacity (personal conversation, Clary, 2009)





Vertical Borehole Loops Horizontal Loops Slinky Loops Pond or Lake Loops

Several configurations are possible for closed-loop systems, the two most common being vertical borehole loops and horizontal trench or ground loops. Horizontal ground loops are typically installed between 6 and 12 feet below the ground surface, depending on the local frost depth and the water table. The pipe can be laid in trenches or pits in a linear pattern, or coiled in "slinky" loops that create overlapping layers. Lake loops are cheaper to install and require shorter overall piping lengths, but they may require a permit from the department. In addition, care must be taken in shallow water to prevent boats and



Direct Exchange

other watercraft from snagging and damaging the pipes. A variation of the closed loop system is the direct exchange (DX) system, where copper pipe or tubing is placed in the ground instead of plastic pipe. The direct exchange system is directly is analogues to the coils in a refrigerator, but the coils are in the ground, not exposed to air.

Open Loop. Water from a surface water source (ocean, lake or river) or groundwater is pumped through the heat exchanger and then discharged back to a water body or onto the ground surface. Open loop systems can cost less than a closed loop system, because their installation involves less new construction. They also can have an efficiency that is comparable to or higher than a closed-loop system. However, state and local codes and regulations regarding discharge must be met. A consistent water supply is crucial to ensure uninterrupted operation and a long service life (Siegenthaler, 2004). Open loop systems have several factors which have reduced their number of installation over recent years. In cold climates, such as Wisconsin, open loop systems are limited due to freezing temperatures that can make the water source unavailable, cause pipes to freeze or limit disposal options. Secondly, because open loop systems use native water, they can have scaling or mineral build-up over time, which requires periodic maintenance with de-scalars or delimers. Also, bacterial growth can be a problem under certain conditions.

Single Well Pass-through

Open Loop - Pond or Lake Loop

Types of System Installations

The number of installations for each type of system configuration is not readily available in Wisconsin. The department, through our approval process, over the last 10 years (2002-2011) has approved the installation of 1517 vertical closed loop borehole systems. Personal discussion with the two top installers of vertical borehole systems over the past three years indicated that the firm located in western Wisconsin is installing approximately 80% vertical closed loop systems and 20% horizontal closed loop systems. The high number of vertical installations is due to the specific geology encountered in the western part of the state, where you find bedrock ridges and dry sandy soil. Our major vertical loop installer, located in the Northeast region, installs approximately 65% horizontal (trench or directional boring) systems and 45% vertical borehole systems (personal conversation, Oosterhouse & Flocks, 2012). Conversations with two separate geothermal heat pump suppliers in Wisconsin, confirmed similar installation numbers of 60-65% horizontal systems and 35-40% vertical system installations, from these companies (personal conversation, Urlaub and Nissan, 2012).

Heat Distribution and Storage

In 2008, there were 23 heat pump manufacturers in the U.S. (Battocletti & Glassley, 2010). A wide range of heat pump units is available on the market, from small residential 3-ton systems to large 100-ton units. Heat pumps generally accept a broad range of entering water temperatures (EWTs), from approximately 20°F to 120°F, and supply heat up to about 120°F. The units are designed for cooling or heating only, or are designed with both heating and cooling capacity. The designed size of the system in tons (tonnage reflects how much energy the system is capable of transferring). 1 ton equals 12,000 British thermal units [BTUs] per hour.

Heat Pumps are Defined by their Method of Heat Delivery

Forced-air units. A forced-air unit directly heats air to be distributed through ductwork. These systems can also be used for cooling if the heat pump is reversed for air-conditioning application.

Hydronic. A GSHP application requires hydronic distribution to radiant floor or panel distribution, as it is impractical for heat pumps to produce high enough water temperatures for hydronic baseboard distribution. These units heat water in a number of applications. Radiant floor heating is the most common application, although these units also can be coupled with a fan coil for air conditioning or coupled with the domestic hot water (DHW) system.

Combination. Combination units can produce hot water or air.

Desuperheaters. The output from the heat pump compressor can provide high-grade ("super") heat useful for DHW production. As such, a fraction of the heat generated for space can be diverted for providing hot water at temperatures around 160°F (Oklahoma State University, 1997). Depending on the design of the heat pump, the desuperheater can be used to provide supplemental or complete DHW demand. When the heat pump is in heating mode, the heat extracted by the desuperheater subtracts from the supply available for space heating. When in cooling mode, the desuperheater captures heat that would otherwise be rejected to the ground.

Storage Tanks

The addition of a water storage tank as part of a heat pump system can provide operational advantages. The heat pump is used to maintain the water storage tank within a given range of temperatures, and the heat distribution system runs off the water storage tank. The storage tank acts as a heat reservoir to buffer the heat pump from small and frequent space-heating demands, and the heat pump can then operate on longer runtimes with fewer on-off cycles (Siegenthaler, 2004). A water storage tank also can store heat for use during peak power periods, allowing the heat pump to run during off-peak hours. In some areas of the country, heat pump owners can then qualify for discounted rates from utility companies.

Performance Measurements

A common measure of efficiency for combustion heaters, such as a furnace or boiler, is the annual fuel utilization efficiency (AFUE). The AFUE represents the average efficiency for a particular heating appliance over an entire heating season, and is a measure of the amount of heat delivered to a space relative to the amount of fuel delivered to the heating device. For example, a mid-efficiency natural gas furnace may have an AFUE of 80%, meaning that 20% of the heating potential of the natural gas delivered to the furnace is lost due to inefficiencies in the heating system. Such inefficiencies can include cyclic operation, stack losses and standby losses. An electric resistance heater has an AFUE of 100%, as all of the supplied electricity to the unit is converted to heat.

Gas Furnace

The AFUE is not an appropriate measure of efficiency for a heat pump. A heat pump does not convert fuel to heat, but rather uses electricity to lift the temperature of its source (the fluid temperature from the ground loop) to a higher temperature used for space heating. For GSHPs in a heating mode, the most commonly used measure of efficiency is the coefficient of performance (COP). The COP is the ratio of heat output to work supplied to the system in the form of electricity.

$$COP = \frac{Quantity\ of\ Heat\ Delivered}{Energy\ Required\ by\ the\ Heat\ Pump}$$

For example, for electric resistance heating, the COP is 1: all of the electric energy is converted into heat. The energy required by a GSHP is also electrical, and includes the energy needed to run the compressor in the heat pump. Heat pumps have COPs higher than 1 because the energy delivered from a ground source is greater than the energy required to run the heat pump. A typical COP for a heat pump system is in the range of 3 to 4. This corresponds to an "efficiency" of 300-400%. Some of the latest GSHPs have an efficiency of up to 700%, but this may be a result of industry-wide non-standard evaluation testing (personal conversation, Flocks, 2012).

Commonly Recognized Advantages and Disadvantages of Heat Pumps

As with any heating system, GSHPs have a number of advantages and disadvantages for their users. The aspects discussed below are commonly recognized attributes for GSHPs.

Technical Efficiency. The most obvious advantages of GSHPs are their potential for superior efficiency and cost-effectiveness over conventional heating methods. For example, a heat pump with a COP greater than 1 will have a system efficiency greater than an electric resistance heating methods. In analyzing 184 case studies, Lienau, Boyd, and Rogers (1995) found that the average energy savings of GSHP systems ranges from 31% to 71% over heating and cooling systems that use natural gas, heating oil, electric resistance, or air source heat pumps in residential structures. However, 23% of those case studies that used natural gas or heating oil had annual operating costs lower than GSHP systems, demonstrating that energy cost savings are not guaranteed, but dependent on local fuel costs and availability. Similar energy-saving potential was found in 26 case studies of schools and 46 case studies of commercial buildings (Lienau, Boyd, & Rogers, 1995). As energy prices continue to change, the energy savings potential of a GSHP system will be affected.

Demand Side Management. Local utilities throughout the U.S. have taken an interest in GSHP technology for its potential to reduce peak load demand, to obtain new customers where the original systems are based on oil or gas, or to reduce overall demand by replacing electric heating systems with more efficient GSHPs (Lienau, Boyd, & Rogers, 1995). This management method, referred to as Demand Side Management (DSM), is becoming more important as energy demands and costs of new power-generation capacity increase. Customers benefit from discounted electricity rates, ground-loop installation, and special financing (Lienau, Boyd, & Rogers, 1995).

A GSHP installation can reduce electrical demand when replacing an electric heating system. In replacing other types of heating systems, the GSHP increases electrical usage, but if the system incorporates a heat storage system, it can be used to reduce demand during times of peak electrical use. In these systems, the GSHP heats a storage tank during non-peak hours, then the storage tank is used to heat the building during high demand hours.

Ground Loop Emplacement. A substantial limitation of GSHPs is the space needed for a horizontal ground loop. For example, a well-insulated 2000-square-foot home might need a 3-ton system with 1200 to 1800 feet of pipe (NRC Office of Energy Efficiency, 2004). Since this length of pipe is laid in trenches near the home, a substantial amount of land area is needed. Additionally, good access is needed for excavating equipment. These values are much larger for a commercial system. This ground-loop footprint can be reduced if vertical borehole systems are installed. However, vertical systems present other problems, such as access of equipment and the availability of drilling rigs.

Horizontal Slinky Loop

Financial. High capital cost compared with conventional heating and cooling systems is a disadvantage of GSHPs. The higher cost is mainly due to the additional labor and material required to install the ground loop, which can result in a GSHP installation costs that are twice as much as a conventional system (Lienau, Boyd, & Rogers, 1995). In fact, one of the largest barriers to GSHP implementation is the capital cost (Hughes, 2008). These costs can be offset by state and federal rebates. While hampered by high initial costs, GSHP systems can provide savings over time by lower operating costs. As discussed previously, Lienau, Boyd, and Rogers (1995) found that the average annual savings of GSHP systems in residential case studies ranged from 18% to 54% over heating and cooling systems that use natural gas, heating oil, electric resistance, or air source heat pumps. Savings in operating costs for the school case studies ranged from 13% to 58%, and savings for the commercial building case studies ranged from 31% to 56% (Lienau, Boyd, & Rogers, 1995). Hanova and Dowlatabadi (2007) showed annual savings in Canada that average more than $1,500 over electric heating systems, and more than $1,600 over systems that use heating oil. Such financial savings are most dependent on relatively inexpensive electricity. Another factor relevant for determining financial savings is the building energy demand. Energy intensive buildings, such as those with a high number of annual operating hours, high ventilation rates, or high process loads, can generate greater energy savings to offset the capital cost.

Electric Heating

Hybrid Technology May Improve the Performance of Cold Climate GSHPs

Research suggests that hybrid systems are best for climates that are strongly heating or cooling dominated (Yang, Zhou, Xu, & Zhang, 2010) and that hybridization is sometimes necessary for cost-effectiveness (DoD, 2007). Hybrid GSHPs have the potential to prevent thermal degradation of the soil or aquifer over time, to maintain more efficient heat pump operation throughout the heating season, and to perform well over time. Most hybrid heating systems consist of a typical GSHP system that is augmented with a solar thermal system, used for supplementing the heat obtained from the ground loop in winter and for recharging the ground during summer. Such an innovative approach of using solar heat or waste heat to recharge the ground loop holds promise for using a GSHP in a cold climate (Straube, 2009).

Solar Panels
(Madison home)

It should be noted that while hybrid GSHPs may perform better than non-hybrid GSHP in heating-dominated climates, they are not necessarily significantly more economical. While it's probable that a hybrid GSHP will have a higher COP than a non-hybrid GSHP in the same location, hybrid systems will also presumably have higher capital costs. Whether the additional capital cost provides sufficient reductions in operating cost (by improving COP) to justify the system hybridization is a highly site specific consideration.

Current Trends

A major shift or trend brought up in conversation with several companies, along the lines of types of systems being installed, was the substantial reduction in numbers of open loop or pump and dump systems were being installed these days, as opposed to the past. Companies are installing very few open loop systems, generally because of the issues with the volume of open loop fluid to be disposed of and the problem of finding suitable disposal locations on or near the site. A second installation trend has been the switch toward installation of systems using directional boring technology (personal conversation, Urlaub and Nissan, 2012).


Control Circuit Board

Conversations with representatives from the major GSHP manufactures all indicate that the current hardware trends in the industry are currently along three avenues. The first being the introduction of more sophisticated control systems to manage the units. Circuit boards are becoming what differentiate one GSHP unit for the competitor's unit. One GSHP unit is basically the same as the competitor's product, but with the addition of more sensors for additional monitoring and more advanced control software, the units are capable of doing much more for the owner. The highest end systems are being designed to integrate the entire house heat and cooling as well as the electrical demand under one control unit. Owners are able to monitor a vast array of performance information related to flow and temperature, as well as monitor overall energy usage.

A second major trend in hardware is inclusion of the advanced multi-stage compressors and variable speed pumps into the systems being sold. A single stage GSHP uses the same rate of transfer at all times during operation. A dual stage (also called a 2 stage), uses 2 different rates of transfer. Two stages are akin to a "high" and a "low." When the target or desired temperature and current or measured temperature are fairly close in number, the unit will not need to work as hard, thus using the "low" setting. In this case, a low rate of transfer is all that is necessary for getting to the desired temperature. Conversely, when the difference in temperature is high, and the unit needs to change the temperature several degrees quickly, the dual stage heat pump will switch over to the high rate of transfer and more energy will be used to get the job done (Heat Pump Reviews, website). The incorporation of variable speed pumps allows the system to use less energy by allowing a more gradual start-up of the motor, where a single speed pump kicks on, working to get to full speed and using much more electricity. Both of these advancements in design, the multi-stage compressor and the variable speed pumps, increase efficiency of the entire system and decrease the amount of electricity used, thus reducing the operational cost.

The merging of multiple types of system technology into one complete, self-sufficient package is becoming more common. Systems that incorporate a GSHP and solar cells for electrical power generation are currently considered the top of the line, and command top dollar. The inclusion of solar cells, to generate electrical power, allows for a large reduction in the amount of grid electricity consumed while operating the pumps and compressor. Excess power can actually be sold back to the local grid to offset higher electricity costs. Solar cells can also allow the system to run extra during what would in essence be off cycles, and use these extra cycles to actually dump excess heat back into the aquifer in the winter months. Adding heat back into the aquifer prevents the aquifer from cooling down as much as is normally expected, and can greatly boost efficacy. The higher the temperature is in the aquifer, the greater the efficacy of the GSHP is due to the higher amount of heat available for extraction, thus requiring lower energy required to extract that heat. With no increased costs, these extra cycles can be added without incurring an out of pocket penalty. As solar cell costs continue to drop, these systems will become more common and more affordable. Solar cell

technology is still expensive for the average homeowner, but groups such are Madison's own, Willy Street Coop, are using the power of group buying to help bring down the costs.

The GSHP manufactures obviously want there to be a trend toward purchasing more units and installing more systems, which trades off the use of a non-renewable fossil fuel for a slight increase in electricity consumption. The industry, in conjunction with trying to increase sales, is also looking and working toward making geothermal a truly "green technology," by integrating solar power generation as a component of the system. The industry as a whole also began to lobby for a shift in the commercial grid production of electricity toward an increasing percentage generated through renewable alternatives such a wind and solar and away from coal fired generation.

Barriers to GSHP Technology Adoption

The major barrier to adoption of GSHP technology is the higher initial cost of installation of a GSHP system as compared to a conventional furnace/air conditioning system. Installation costs for a 5-ton vertical borehole GSHP system can run in the range of $20,000 - $26,000. Typical costs for installation of a conventional central furnace/air conditioner system run $5,000 - $9,000.

Stories of failed system installations or poor performing systems often holdback new adopters. Conversations with several system installers, relayed the issue that in some areas of Wisconsin, they have a tough time selling GSHP system, because of the past system problems or bad installations in the area.

The lack of qualified/certified installers in an area goes hand in hand with the problems of failed systems and installations. This issue to varying degrees is still a problem, from the standpoint of installer experience. The training and certification issue has virtually disappeared with the proliferation of International Ground Source Heat Pump Association (IGSHPA) training and the abundance of certification classed for installers, designers and drillers. A recent conversation with a GSHP company representative provided some key insight into one of the industries major remaining hurdles to quality system installations. He indicated that he is still seeing installers who were not doing the actual heat load calculations and still relying on rules of thumb. Certification training teaches you to rely on software for this, but oftentimes you still have to overcoming previous work experience or bad habits (personal conversation, Green).

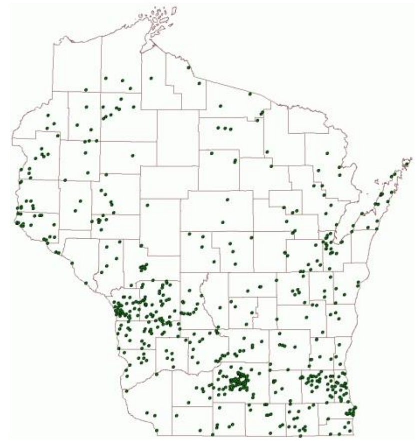
Lack of homeowner rebate incentives stifles adoption of the technology. Rebates are one of the best ways to get the individual's attention and thus generate interest in a new product. The U.S government currently offers a 30% tax incentive rebate for a new residential system and 10% for a new commercial system installation. While this is substantial, Wisconsin utilities as well as the state have been slow in making additional rebate/insensitive monies available at the local level. The smaller co-op utilities have been in the forefront of offering rebate incentives in Wisconsin for geothermal installations. This changed as of July 2, 2012, with Focus on Energy's new Residential Rewards Program, with a section targeted at Renewable Geothermal Heat Pumps. The current rebate provides $650 for a geothermal heat pump replacement installation of an existing system. The program has a limited amount of money and is being run on a first come first serve basis, but is a good start toward helping to promote more adoption of the technology in the state.

The Potential Downside of Geothermal Technology

Geothermal technology seems to have relatively few issues to be concerned about, but as with any technology, there are a few issues or risks, which should be noted.

Vertical Drillhole Installations

Vertical drillhole closed loop systems are perhaps the most prone to potential issues, because of the drilling aspect of their installation. Drilling is an invasive technology which by its very nature will carry some risk to the groundwater aquifer. Drilling a vertical closed loop system generally requires from 150 to 300 feet of drillhole for each vertical loop installed. Residential systems have been approved for as few as two, to as many as thirty-five drillholes. The latest EPIC site expansion project which finished up in early 2012, installed 2000 drillholes, to bring their total up to 3576 drillholes for three different installations. Stepping back to look at the overall big picture view, in 2010 there were 248 geothermal projects approved, requiring 2255 individual drillholes. In 2011, there was a second straight yearly downturn in approvals, but 166 geothermal projects were approved, requiring 3819 individual drillholes of between 5 and 6 inches in diameter. As a point of comparison, in 2011, there were 6692 total water supply wells drilled in Wisconsin.



Distribution of 630 Geothermal Projects Oct. 2009- Sep. 2012

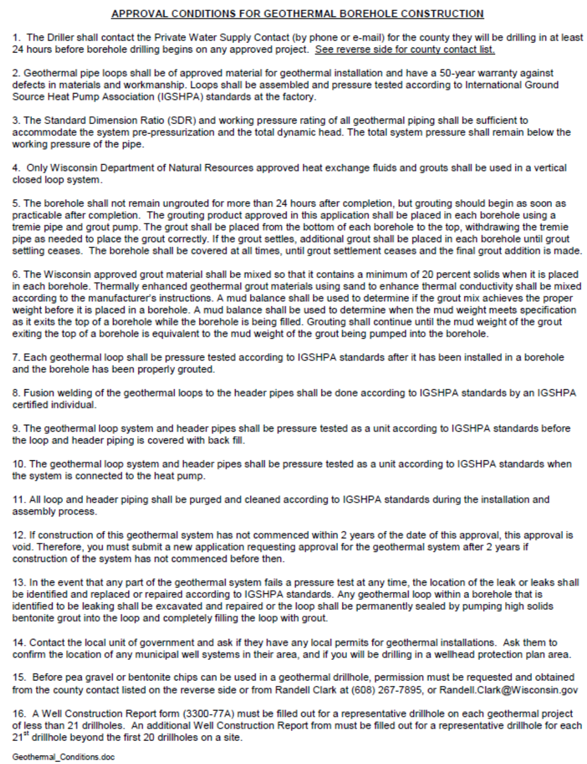
Potential Vertical Drillhole Problems

Vertical drillholes have three obvious potential issues. The first issue being that a drillhole can cross-connect multiple aquifers while it remains unsealed or ungrouted. As shown in the cover image, a drillhole being drilled adjacent a previous hole, has an obvious connection to the active drilling, as seen by water shooting out the top of the previously drilled hole. This is not unique to geothermal drilling, but because geothermal drillholes are more closely spaced, usually in a grid pattern with spacing between drillholes of 15 to 20 feet, than neighboring water supply wells, this has a greater potential to occur. To address this issue the department, in one of the sixteen geothermal project approval conditions, condition #5, asks that the drillhole not remain ungrouted for more than 24 hours, but grouting should begin as soon as practicable after completion. The department also reviews each application and checks local well construction logs in the area for notation of fractures and voids. A newly added condition requires that the driller contact the department if fractures or voids are encountered which require the use of pea gravel or bentonite chips to bridge across the void, and prevent excessive loss of grout to the formation. The department is keeping a list of locations where pea gravel or chips are being used for both water supply wells and geothermal drillholes, and is developing a GIS application to display those well or drillhole location on a map for staff. If staff no longer review each application in the future, then a review of local site geology will not be done.

Drillhole Cross-Connection

A second potential issue is that the open drillhole can provide a conduit for surface contamination to enter. While the intent is to have the drillhole remain open for a minimum of time, it does provide a pathway for surface contaminants to reach the lower aquifer while open. To address this issue the department, through condition #5, asks, as above, that the drillhole not remain ungrouted for more than 24 hours, but grouting should begin as soon as practicable after completion. In addition, the borehole shall be covered at all times, until grout settlement ceases and the final grout addition is made.

A third potential issue for geothermal drillholes is that a poor grout job can still leave the aquifer susceptible to surface contamination, cross-connection or cross-contamination if one aquifer has contamination already present. The department is addressing this issue with two specific approval conditions. Approval condition #4, states that only DNR approved grout products may be used. The fifth conditions states that the grouting product approved in the application shall be placed in each borehole using a tremie pipe and grout pump. The grout shall be placed from the bottom of each borehole to the top, withdrawing the tremie pipe as needed to place the grout correctly. If the grout settles, additional grout shall be placed in each borehole until grout settling ceases. The Wisconsin approved grout material shall be mixed so that it contains a minimum of 20 percent solids when it is placed in each borehole. Thermally enhanced geothermal grout materials using sand to enhance thermal conductivity shall be mixed according to the manufacturer's instructions. A mud balance shall be used to determine if the grout mix achieves the proper weight before it is placed in a borehole. A mud balance shall be used to determine when the mud weight meets specification as it exits the top of a borehole while the borehole is being filled. Grouting shall continue until the mud weight of the grout exiting the top of a borehole is equivalent to the mud weight of the grout being pumped into the borehole. To address the contamination potential, the department reviews each site location for known contamination issues. If contamination is identified on or near the drilling site, an investigation is initiated by review staff and the contamination potential is evaluated. The driller is notified and the issues of drilling near potential contamination are discussed. If staff no longer review each application in the future, then a potential contamination review will not be done.



APPROVAL CONDITIONS FOR GEOTHERMAL BOREHOLE CONSTRUCTION

1. The Driller shall contact the Private Water Supply Contact (by phone or e-mail) for the county they will be drilling in at least 24 hours before borehole drilling begins on any approved project. See reverse side for county contact list.

2. Geothermal pipe loops shall be of approved material for geothermal installation and have a 50-year warranty against defects in materials and workmanship. Loops shall be assembled and pressure tested according to International Ground Source Heat Pump Association (IGSHPA) standards at the factory.

3. The Standard Dimension Ratio (SDR) and working pressure rating of all geothermal piping shall be sufficient to accommodate the system pre-pressurization and the total dynamic head. The total system pressure shall remain below the working pressure of the pipe.

4. Only Wisconsin Department of Natural Resources approved heat exchange fluids and grouts shall be used in a vertical closed loop system.

5. The borehole shall not remain ungrouted for more than 24 hours after completion, but grouting should begin as soon as practicable after completion. The grouting product approved in this application shall be placed in each borehole using a tremie pipe and grout pump. The grout shall be placed from the bottom of each borehole to the top, withdrawing the tremie pipe as needed to place the grout correctly. If the grout settles, additional grout shall be placed in each borehole until grout settling ceases. The borehole shall be covered at all times, until grout settlement ceases and the final grout addition is made.

6. The Wisconsin approved grout material shall be mixed so that it contains a minimum of 20 percent solids when it is placed in each borehole. Thermally enhanced geothermal grout materials using sand to enhance thermal conductivity shall be mixed according to the manufacturer's instructions. A mud balance shall be used to determine if the grout mix achieves the proper weight before it is placed in a borehole. A mud balance shall be used to determine when the mud weight meets specification as it exits the top of a borehole while the borehole is being filled. Grouting shall continue until the mud weight of the grout exiting the top of a borehole is equivalent to the mud weight of the grout being pumped into the borehole.

7. Each geothermal loop shall be pressure tested according to IGSHPA standards after it has been installed in a borehole and the borehole has been properly grouted.

8. Fusion welding of the geothermal loops to the header pipes shall be done according to IGSHPA standards by an IGSHPA certified individual.

9. The geothermal loop system and header pipes shall be pressure tested as a unit according to IGSHPA standards before the loop and header piping is covered with back fill.

10. The geothermal loop system and header pipes shall be pressure tested as a unit according to IGSHPA standards when the system is connected to the heat pump.

11. All loop and header piping shall be purged and cleaned according to IGSHPA standards during the installation and assembly process.

12. If construction of this geothermal system has not commenced within 2 years of the date of this approval, this approval is void. Therefore, you must submit a new application requesting approval for the geothermal system after 2 years if construction of the system has not commenced before then.

13. In the event that any part of the geothermal system fails a pressure test at any time, the location of the leak or leaks shall be identified and replaced or repaired according to IGSHPA standards. Any geothermal loop within a borehole that is identified to be leaking shall be excavated and repaired or the loop shall be permanently sealed by pumping high solids bentonite grout into the loop and completely filling the loop with grout.

14. Contact the local unit of government and ask if they have any local permits for geothermal installations. Ask them to confirm the location of any municipal well systems in their area, and if you will be drilling in a wellhead protection plan area.

15. Before pea gravel or bentonite chips can be used in a geothermal drillhole, permission must be requested and obtained from the county contact listed on the reverse side or from Randell Clark at (608) 267-7895, or Randell.Clark@Wisconsin.gov

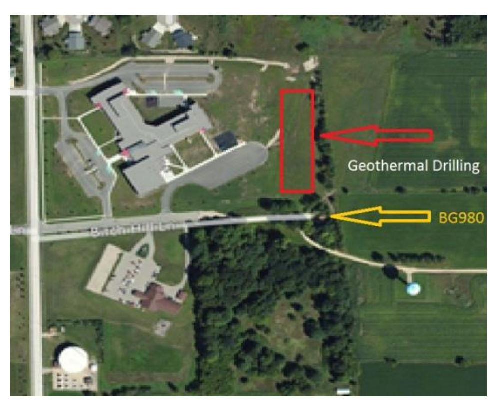
16. A Well Construction Report form (3300-77A) must be filled out for a representative drillhole on each geothermal project of less than 21 drillholes. An additional Well Construction Report from must be filled out for a representative drillhole for each 21st drillhole beyond the first 20 drillholes on a site.

Geothermal_Conditions.doc

Approval Conditions

Known Geothermal Problems

Wisconsin has seen one documented case of drilling on a geothermal project causing a problem for a municipal well. The Shawano Middle School project, approved in 2009, drilled several drillholes within approximately 110 feet of Shawano well BG980. Through investigation of the problem by the DNR Water Supply engineer and discussions about the problem with all others involved, it was determined that the drilling and grouting may have disturbed the formation along a natural bedding plane and caused the municipal well pump to uptake sand and sediment. The problem was discovered through a positive



Shawano School and Shawano Well BG980

bacti sample and persistent cloudiness of the water being sampled (department e-mail, Kubly, 2009). The final cost of dealing with this problem was listed at approximately $250,000. (Stautz, 2012) Even though an existing project approval condition required that the project check with the City of Shawano for nearby wells, this was not done. The problem was solved by shutting down pumping of the well for the duration of the geothermal drilling and grouting. Current review protocol is setup to notify the regional Water Supply engineer and the well driller if a project is approved within 1200 feet of a municipal well. If staff no longer review each application in the future, then a review for nearby municipal wells will not be done and no notifications will take place by department staff.

A second documented problem, this time with a private water supply well, was discovered back in 2009, at a site SE of La Crosse near the border of Vernon County. The water quality in the Deb and Al Reilly well went extremely bad after drilling four nearby geothermal drillholes. The drillholes encountered a large void from 50-55 feet below ground surface. Information from the original well construction log shows 55 gallons worth of pea gravel were required to fill the 5-foot void. Water quality in several well samples showed levels of aluminum at 67,00 ug/L, arsenic at 92 ug/L, copper at 1,290 ug/L, iron at 1,290 ug/l, manganese at 2,980 ug/L, nickel at 1,750 ug/l, and zinc at 4,400 ug/L, to document a few of the highest parameters. The well was eventually replaced in 2010, with a deeper cased well and water quality returned to acceptable levels (personal conversation, Johnson, 2012). This highlights the fact that nearby drilling and grouting has the potential to dramatically change local flow systems and can cause drastic chemical water quality changes to occur.

Reilly Property

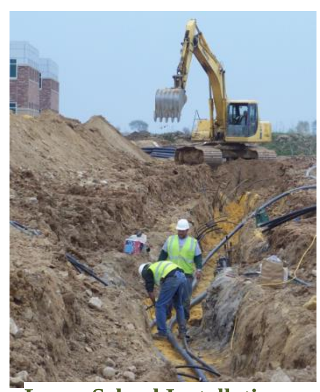
Geology Codes	8. Geology Type, Caving/Noncaving, Color, Hardness, etc	From (ft.)	To (ft.)
__C_	CLAY	0	15
G_H_	SHALE GRAY	15	50
_C__	VOID	50	55
E_H_	GREEN SHALE	55	140
T_N_	BROWN SANDSTONE	140	200

Reilly's Old Well Construction Log

There are other instances of nearby private wells having been affected by a geothermal project, but these are isolated. They do however occur and it needs to be noted that they will continue to happen as a result of drilling multiple, closely spaced drillholes in the vicinity of an existing water supply well.

Issues for the Future

Three issues of concern, which need to be watched and may need to be addressed at some time in the near future are the abandonment or decommissioning of old systems, the additional risks inherent in the direct exchange (DX) systems and the potential thermal impacts that a large geothermal installation could exert on the local groundwater flow system. Geothermal systems are projected to have a long functioning lifespan. The high density polyethylene (HDPE) tubing is being warranted currently by the manufacturer for 50 years, and is projected to last on the order of 100 years. The mechanical GSHP unit is expected to operate anywhere from 10 to 20 years, similar to existing furnace technology. The issue of concern is not the GSHP unit inside, but the buried HDPE loops outside the structure. The current paper approval documentation will most likely be insufficient to track the location of these systems for much into the foreseeable future. While the paper copy of a project approval is fairly detailed as to the location and



Large School Installation where Individual Drillhole Loops are being Tided into the Main Trench Lateral Feed Line

orientation of the geothermal system on each site, it is unlikely to remain readily available or accessible for future reference. A long-term solution is however currently available. If these systems were to be included in the Diggers Hotline system, then in the long term, their potential for future discovery is almost assured. These are not public utility pipes, but are in essence buried private utility pipes on the property. These pipes, if damaged, are expensive enough to warrant consideration for inclusion into the Diggers Hotline system.

A second issue, which bears watching, is the installation of Direct Exchange (DX) systems. DX systems currently are only approved on an experimental basis as part of the certified training program developed at Gateway Technical Institute in Racine, but a few inquiries have been made into the feasibility for commercial installations. DX systems do not use multiple plastic pipe loops, but use a single copper pipe loop buried in the ground. Direct exchange systems are more efficient and have potentially lower installation costs than closed loop fluid systems. Copper's high thermal conductivity contributes to the higher efficiency of the system, but heat flow is predominantly limited by the thermal conductivity of the ground, not the pipe. The main reasons for the higher efficiency are the elimination of the water pump (which uses electricity), the elimination of the water-to-refrigerant heat exchanger (which is a source of heat loss), and most importantly, the latent heat phase change of the refrigerant in the ground itself. A direct exchange system requires only 15 to 30% of the length of tubing and half the diameter of drilled holes, and the drilling or excavation costs are therefore lower. A downside to installation is the copper loop must be protected from corrosion in acidic soil through the use of a sacrificial anode or other cathodic protection measures (Wikipedia, 2012).

Another issue with DX systems is the use of a fluid/gas circulating in the copper pipe loop that has not been reviewed by the state or certified groundwater safe, as is done with vertical loop fluids. These systems use many of the same refrigerant products used in current refrigerator technology. R-410A has replaced R-22 as the preferred refrigerant for use in residential and commercial air conditioners and heat pump units in Japan, Europe and the United States. R-410A, sold under the trademarked names Puron, EcoFluor R410, Genetron R410A, and AZ-20, is a zeotropic, but near-azeotropic mixture of difluoromethane (CH_2F_2, called R-32) and pentafluoroethane (CHF_2CF_3, called R-125). Unlike alkyl halide refrigerants that contain bromine or chlorine, R-410A (which contains only fluorine) does not contribute to ozone depletion, and is therefore becoming more widely used, as so-called ozone-depleting refrigerants like R-22 are phased out. The refrigerant R-410A does have an environmental downside, with a high global warming potential (1725 times the effect of carbon dioxide), similar to that of refrigerant R-22 it is replacing. Global-warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide (Wikipedia, 2012).

Health effects of over exposure to R-410A may cause dizziness and loss of concentration. At higher levels, central nervous system depression and cardiac arrhythmia may result from exposure. Vapors displace air and can cause asphyxiation in confined spaces. At higher temperatures, greater than 250° C, decomposition products may include Hydrofluoric Acid (HF) and carbonyl halides

The third issue for consideration, and a good candidate for future research, is the thermal influence a large geothermal installation exerts on the local groundwater flow system. It is documented that a geothermal loop does influence the localized temperature around the drillhole. Loop temperatures have been documented to drop down below freezing (32 degrees). The theoretical temperature that systems can extract heat down to is -47° F, making it possible to extract heat out of ice (Wikipedia, 2012). These temperatures are however impractical under real world operating parameters, where the operating temperature of a system should be kept above 14° F. Propylene glycol loop fluids become viscous at this 14° F temperature and require more energy to pump (BRESEC, 2004). On the reverse side, summer operating temperatures for the system, can be in the 90 to 100° F range for fluids circulating in the loops. It is a documented fact that a large loop field installation exerts a measurable influence on the local groundwater system. Under the right conditions, a large loop field installation could also be affecting surface water conditions in a localized area, as groundwater flows through and past the installation, picking up heat in the summer months as heat is dumped back into the loops, and cooling down during the winter months as heat is extracted from the loops and the localized area. Some Wisconsin specific research might be invaluable in assessing these large systems and their influence on local groundwater and even nearby surface water flow systems. Projects such as the recent EPIC site installation of 2000 geothermal loops and their proximity to the nearby Sugar River would be a good case in point for further research.

One temperature specific ground loop study, done with data in cooling dominated locations, indicated that the primary reason for elevated loop temperatures were insufficient heat exchanger bore length. Although most of the sites had large cooling mode requirements compared to those in heating, no significant increase in long-term temperature rise were noted. (Kavanaugh, ASHRAE Journal, September 2012)

Geothermal systems that are designed and sized properly are not likely to have long-term temperature fluctuations. Any temperature fluctuations will even out to the yearly average in the long term and there would be a negligible effect on the aquifer over the longer term. However, if systems are not designed and sized properly, then a long-term decline or rise in the aquifer temperature could also occur as a result of these geothermal systems. Software is available to the system designers, which should help to prevent a system from being sized incorrectly. However, training and experience are required to make sure that the available tools are used correctly.